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Purpose and Objectives of the 2013 Evaluation and Screening Effort

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Fuel Cycle Options Campaign**

**USDOE Informational Meeting on
Nuclear Fuel Cycle Evaluation Metrics
November 8-9, 2012**

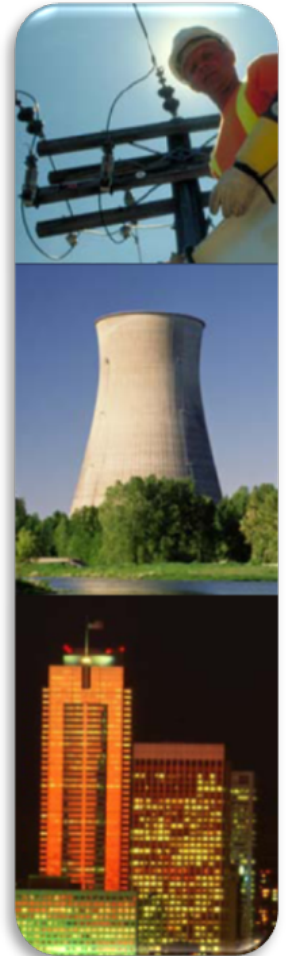


- **Why Evaluate and Screen Fuel Cycles**
- **Charter for 2013 Evaluation and Screening**
- **Evaluation and Screening Approach**
- **Comprehensive Options List**
- **High-Level Evaluation Criteria and Associated Metrics**
- **Path Forward**



Why Evaluate and Screen Fuel Cycles?

- Provides a systematic, objective, and transparent method for evaluating and categorizing nuclear energy systems
- Improves the ability to clearly identify and prioritize R&D needs and better communicate the rationale for R&D directions, funding decisions, and policy-making
- Enhances the ability of the program to formulate and execute program budgets
- Allows the program to more readily adapt to future policy changes and will help in determining how any changes will impact the prioritization of R&D for key technologies





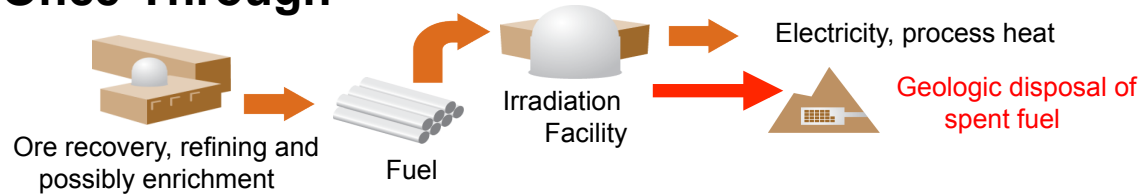
Current Study in Context

- **Many studies on fuel cycles have been done in the past**
 - Typically for a specific purpose, e.g.,
 - Efficiency of uranium use
 - Potential effects on nuclear weapons proliferation
 - Potential benefit for waste disposal
 - Often for a specific set of fuel cycle choices, e.g.,
 - Fast reactors
 - Accelerator Driven Systems
 - Minor actinide recycling
- **This study is to be comprehensive, both in the range of fuel cycles considered and in the range of criteria**
 - No prior study with such a broad scope
 - All potential fuel cycles, once-through and recycle
 - Criteria specified by DOE-NE

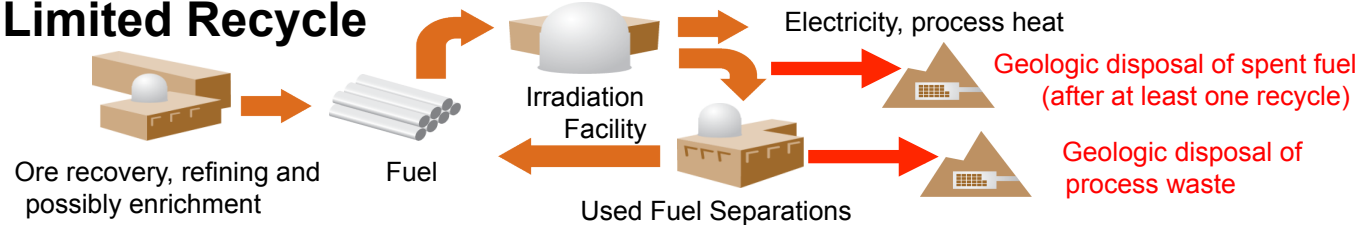


Nuclear Fuel Cycles

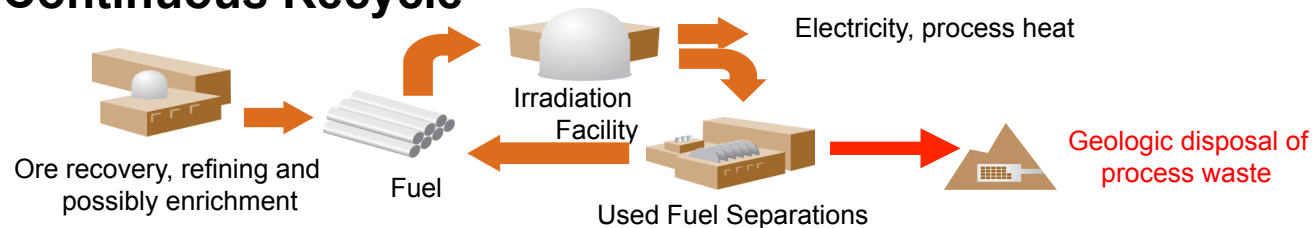
Once-Through



Limited Recycle



Continuous Recycle



- More than one type of irradiation, separations, etc. can be used
- What are the most promising fuel cycles?



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Charter for 2013 Evaluation and Screening



Nuclear Fuel Cycle Options Evaluation and Screening

- **DOE defined the scope for the study in a charter for a Nuclear Fuel Cycle Evaluation and Screening to identify fuel cycles and their characteristics that have beneficial improvements with respect to specific evaluation criteria**
 - The study is to be comprehensive in terms of the fuel cycle options considered
 - Results can be used to inform DOE-NE on R&D directions and funding decisions
- **The Charter was signed December 2011**
- **Final report on study is planned to be issued by May 2014**
 - Activities to date have been focused on developing and completing the preparations for the evaluation and screening
 - An Evaluation and Screening Team (EST) has been established to develop and conduct the fuel cycle evaluation and screening
 - Also established an Independent Review Team (IRT) outside of the FCR&D program (mainly industry & universities)



Evaluation and Screening Team

- **Roald Wigeland – INL, Team Leader**
- **Temi Taiwo – ANL, Deputy Team Leader**
- **Michael Todosow – BNL**
- **Hans Ludewig – BNL**
- **Siegfried Stockinger – DOE-NV**
- **Bill Halsey – LLNL**
- **Jess Gehin – ORNL**
- **Bob Jubin – ORNL**
- **Jim Buelte – Consultant (ex-PNL)**
- **Karen Jenni – Insight Decisions, LLC**
- **Brian Oakley – Scully Capital**



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Independent Review Team – Established by North Wind, LLC

Name	Affiliation
Michael Corradini, Chairman	University of Wisconsin
Tito Bonano	Sandia National Laboratory (SNL)
Bob Hill	Argonne National Laboratory (ANL)
Everett Redmond	Nuclear Energy Institute (NEI)
Neil Todreas	Massachusetts Institute of Technology (MIT)
Bob O'Connor	National Science Foundation (NSF)
Tom Cotton	Complex Systems Group, LLC (CSG)
Dick Stewart	New York University Law School
Tom Isaacs	Lawrence Livermore National Laboratory (LLNL)
Keller Staley, Task Coordinator	Longenecker & Associates, Inc. (L&A)



High-Level Evaluation Criteria

■ The Charter specifies nine high-level evaluation criteria

- Nuclear Waste Management
- Proliferation Risk
- Nuclear Material Security Risk
- Safety
- Financial Risk and Economics
- Environmental Impact
- Resource Utilization
- Development and Deployment Risk
- Institutional Issues



Questions to be Answered

■ For the high-level evaluation criteria

- Which nuclear fuel cycle system options have the potential for substantial beneficial improvements in nuclear fuel cycle performance, and what aspects of the options make these improvements possible?
- Which nuclear material management approaches can favorably impact the performance of fuel cycle options, e.g. extended decay storage (spent or used fuel, products, or wastes), specific disposal environments, processing of used fuel, minor actinide separation and transmutation, etc.?
- Where is DOE R&D investment needed to support the set of promising fuel cycle system options and nuclear material management approaches identified above, and what are the technical objectives of associated technologies?



Independent Review

■ DOE-NE has chartered an Independent Review Team to review major elements of the evaluation and screening project

- Membership of the EST
- High-level evaluation criteria
- Comprehensive fuel cycle options list and grouping
- Fuel cycle evaluation and screening approach
- Evaluation metrics
- Draft final report



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Approach for Evaluation and Screening



Evaluation and Screening Approach

- **The approach for the evaluation and screening was developed from prior studies and a pilot testing of the process (2010-2011)**
 - General approach based on numerous previous fuel cycle evaluations
 - Previous evaluations were limited either in scope of the fuel cycles considered or in the range of criteria being considered
 - Process needs to be applicable to a comprehensive fuel cycle evaluation for a wide range of criteria
 - Deficiencies identified in the pilot testing are being addressed
 - Improve approach for developing comprehensive fuel cycle option list
 - Improve approach for developing appropriate evaluation metrics
 - Develop sufficient data for the evaluation
- **Approach has been documented in a draft report**
 - Revisions continue to be made prior to Independent Review
 - Approach will be finalized after Independent Review



Components of the Overall Approach

■ Development of a comprehensive list of options

- Grouping of options into a small number of evaluation groups

■ Development of evaluation metrics for each high-level criterion

■ Fuel cycle evaluation

- Calculate (estimate) all metric values for each evaluation group
- Determine importance of difference in metric value (utility function)
- Order/rank the evaluation groups in terms of potential benefits on each criterion individually
- Order/rank the evaluation groups in terms of potential benefits considering all criteria
- Requires judgments about the relative importance of the different criteria, which will be explored through sensitivity analyses

■ Fuel cycle screening

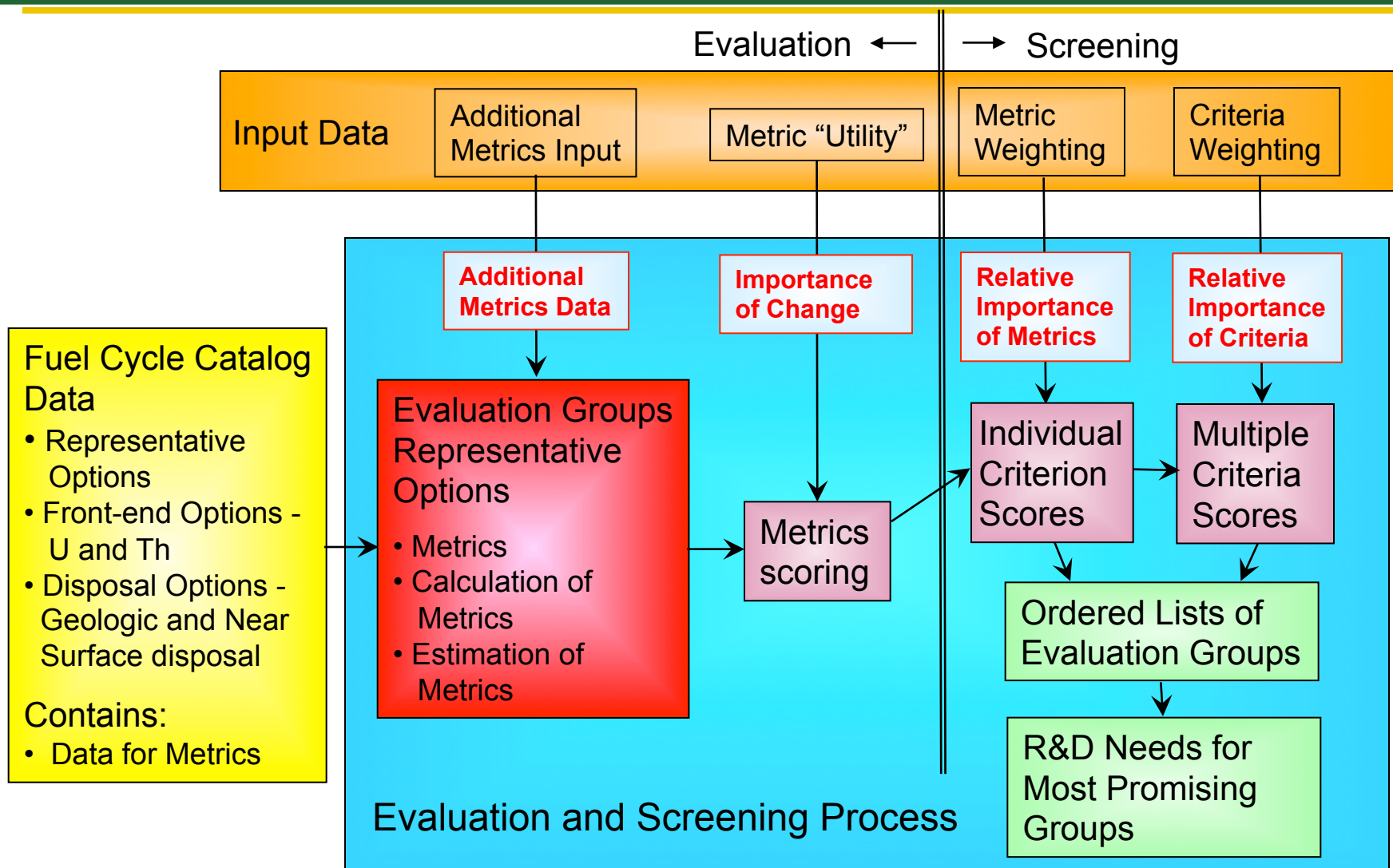
- Most promising fuel cycles are identified based on evaluation and sensitivity analysis result

■ Identification of R&D directions

- Functional and technical requirements are provided for the supporting technologies of the most promising options



Evaluation and Screening Process





Use of Equilibrium Conditions

- **The evaluation and screening considers the fuel cycles at “equilibrium” conditions**
 - Assumes the fuel cycle has been developed and deployed for the purposes of calculating the fuel cycle characteristics such as mass flows, compositions, waste generation, ...
- **The principle is to identify if an alternative fuel cycle would provide a benefit for one or more of the evaluation criteria as compared to a once-through critical thermal reactor system using uranium fuel**
 - Once most promising fuel cycle options are identified, detailed issues of transition will be investigated following this evaluation and screening



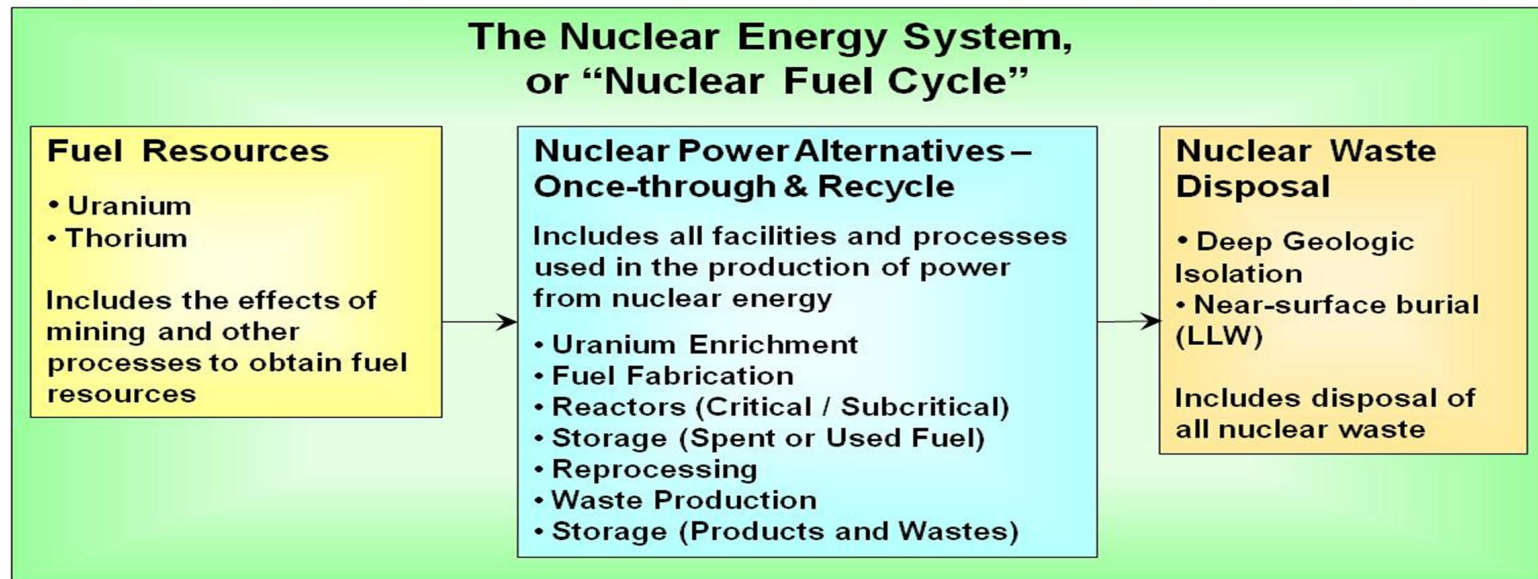
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Comprehensive Fuel Cycle Options List



Nuclear Fuel Cycle Option

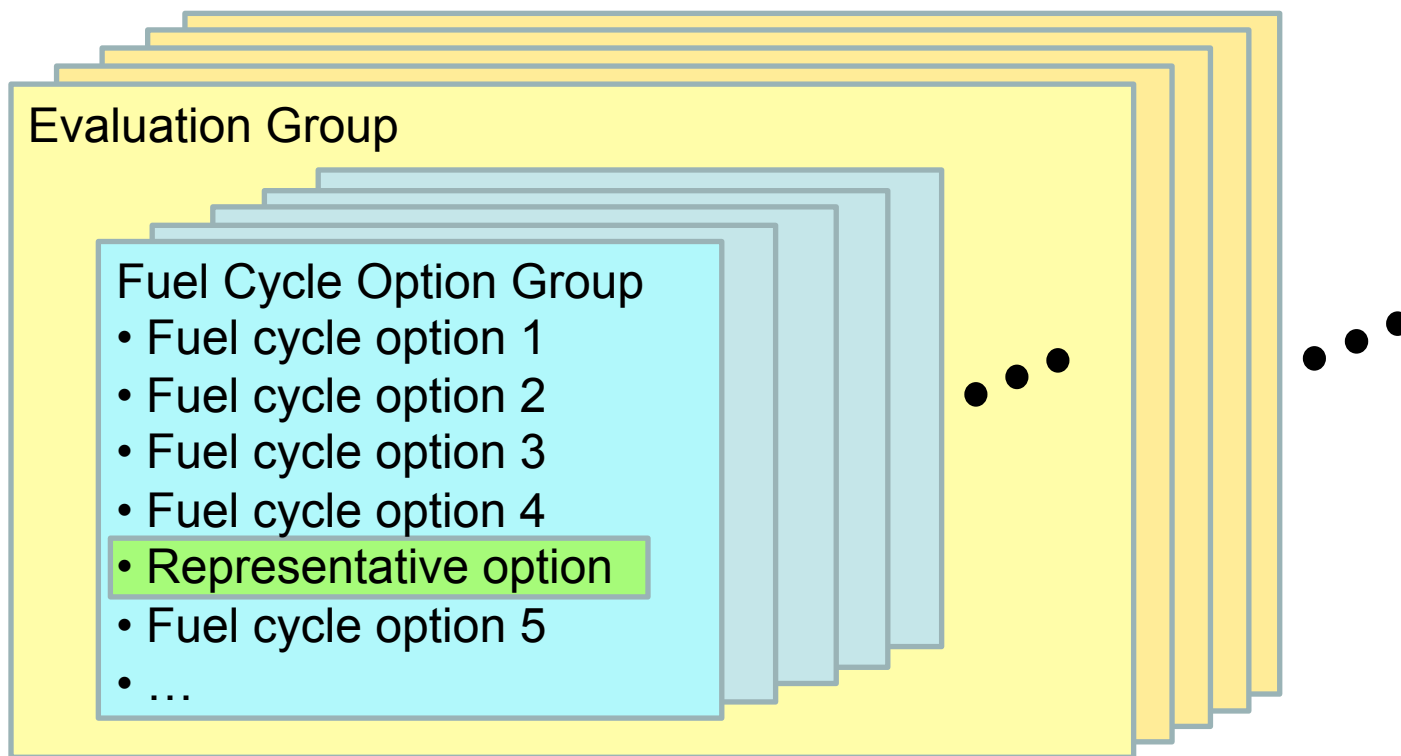


■ **A Nuclear Energy System includes all functions required for using nuclear energy (also known as a nuclear fuel cycle option) from mining to disposal, and everything in between**

- Fuel materials obtained from natural resources
- Nuclear power alternatives for producing power
- Disposal of nuclear wastes, including spent fuel and other high-level wastes requiring deep geologic isolation, and low-level wastes suitable for near-surface burial



Fuel Cycle Options, Groups, and Evaluation Groups



■ Multiple Evaluation Groups

- Each Evaluation Group has one or more Fuel Cycle Option Groups
- Each Fuel Cycle Option Group has one or more Fuel Cycle Options
- One Fuel Cycle Option is the Representative Fuel Cycle Option for the Evaluation Group

■ Fuel Cycle Evaluation and Screening is performed at the Evaluation Group Level



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High-Level Evaluation Criteria and Associated Metrics



Define High-Level Evaluation Criteria

- **The nine high-level evaluation criteria were listed in the Charter for the study**
 - The high-level criteria reflect broadly defined economic, safety, environmental, non-proliferation, security, and sustainability goals
 - The criteria were used in numerous prior fuel cycle studies and in the pilot demonstration of the evaluation and screening process
 - Specific definitions were developed to be consistent with the earlier studies and the intent of representing the broadly defined goals
- **The criteria are not independent of one another**
 - The criteria address high-level issues and goals that are often related to the same fuel cycle characteristics
- **Definitions provided in the next presentation as the metrics are discussed**
 - Definitions are still draft, pending finalization of the metrics



Draft Evaluation Metrics

- **The Charter requires appropriate evaluation metrics to be developed for evaluation and screening of nuclear fuel cycles**
- **Metrics for the high level criteria are being developed:**
 - From prior studies
 - Within the Fuel Cycle Options campaign
 - By collaboration with other FCR&D campaigns, other Offices of DOE, external groups
- **Metrics are designed to be informative on the potential for alternative fuel cycles to provide improvement for each criterion**
- **The current draft metrics are presented at this meeting to obtain feedback from stakeholders**



Summary Draft Evaluation Metrics (24)

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■ Nuclear Waste Management (5)

- Relative Mass of SNF+HLW disposed per energy generated
- Relative Activity of SNF+HLW (10E2 years) per energy generated
- Relative Activity of SNF+HLW (10E5 years) per energy generated
- Relative Mass of DU/RU disposed per energy generated
- Relative Volume of LLW per energy generated

■ Proliferation Risk (3)

- Maximum FOM₁ (nominal fuel cycle material)
- Maximum FOM₁ (material with mis-use technology included in the fuel cycle)
- Maximum FOM₁ (material with clandestine use of any technology)

■ Nuclear Material Security (1)

- Maximum FOM₁ (nominal fuel cycle material)

■ Safety (1)

- Relative Safety Management Challenge

■ Financial Risk and Economics (1)

- Levelized Cost of Electricity at Equilibrium

■ Environmental Impact (5)

- Land Use per unit of energy production
- Water Use per unit of energy production
- Radiological impact - total estimated worker dose per unit of energy production
- Chemical impact - chemical hazard index per unit of energy production
- Carbon impact - CO₂ released per unit of energy production

■ Resource Utilization (2)

- Natural Uranium required per unit of energy production
- Natural Thorium required per unit of energy production

■ Development and Deployment Risk (4)

- Development time
- Development cost
- Compatibility with the existing infrastructure
- Existence of NRC regulations for the fuel cycle and familiarity with licensing

■ Institutional Issues (2)

- Compatibility with the existing infrastructure
- Existence of NRC regulations for the fuel cycle and familiarity with licensing



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Path Forward



- **Feedback from this meeting will be collated and considered by the Evaluation and Screening Team (EST)**
 - A summary report on the meeting will be posted on the meeting website by early December 2012
- **Metrics report will be finalized by the EST**
- **Developed metrics will be subjected to external review by the Independent Review team**